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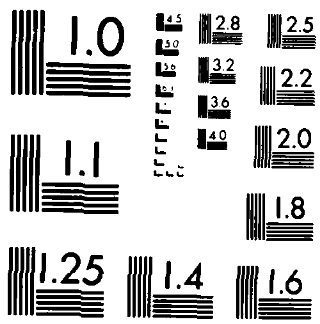

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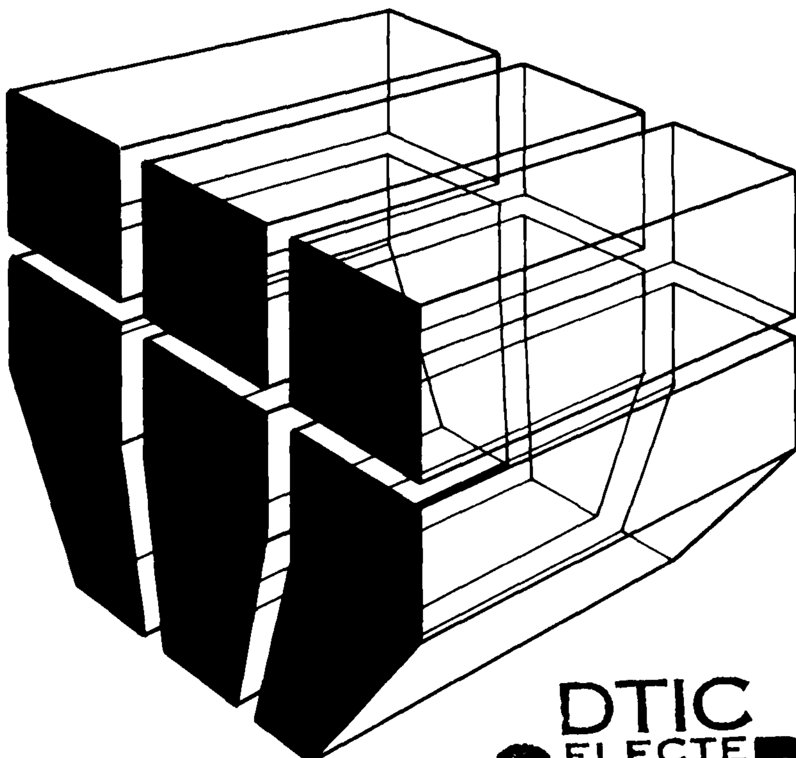
US Army Corps of Engineers
Construction Engineering Research Laboratory

CERL

TECHNICAL REPORT N-85/03
December 1984
Guild Based Training Area Maintenance

THE EFFECTS OF TACTICAL VEHICLE TRAINING ON THE LANDS OF FORT CARSON, COLORADO—AN ECOLOGICAL ASSESSMENT

AD-A152 142



by
Victor E. Diersing
William D. Severinghaus

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FOREWORD

This investigation was performed for the Office of the Assistant Chief of Engineers (ACE) by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (USA-CERL). The work was performed under Project 4A162720A896, "Environmental Quality Technology"; Task A, "Installation Environmental Management Strategy"; Work Unit 030, "Guild Based Training Area Maintenance." The ACE Technical Monitor was Mr. Donald Bandel, DAEN-ZCF-B.

The assistance of the following people is gratefully acknowledged: Steven Emmons, Timothy Prior, and Thomas L. Warren (Environment, Energy, and Natural Resources Office, DEH, Fort Carson, CO); the Colorado Division of Wildlife (James B. Ruch, Director, and John L. Bevard, License Program Administrator); Edward W. Novak and Tony Krzysik (USA-CERL); Steven I. Apfelbaum, Karin A. Heiman, and John A. Prokes (Applied Ecological Services, Juda, WI); and Peter Smith (Camp, Dresser, and McKee, Inc., Denver, CO). Edward W. Novak was the Environmental Resources Team Leader.

Dr. R. K. Jain is Chief of EN. COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

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Extensive field studies were conducted at Fort Carson, CO, to quantify the effects of Army tracked vehicle training on mammals, birds, vegetation, and soils. Ecological variation between two major habitats--pinyon-juniper woodland and shortgrass prairie--was quantified.

Soil disaggregation and increased bulk density resulting from training activities were observed on both habitats. On the pinyon-juniper site, tree and shrub cover decreased, herbaceous cover increased, open-field and edge

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bird guilds increased, and the woodland bird guilds decreased. On the shortgrass prairie site, perennial grass cover decreased, weedy forb production increased, and open-field bird guilds decreased. On both sites, mammals favoring weedy habitats increased. Originator supplied keywords included.

TABLES

FIGURES

FIGURES (Cont'd)

THE EFFECTS OF TACTICAL VEHICLE TRAINING ON THE LANDS OF FORT CARSON, COLORADO--AN ECOLOGICAL ASSESSMENT

1 INTRODUCTION

Background

Meeting defense needs is a primary national concern. To this end, one of the most important and necessary ingredients for the proper training of a standing army is the availability of enough land to conduct training exercises. Since land is a limited resource which is impacted by Army training, land managers and administrators must have scientifically sound information on the quality of Army lands. These data will serve as the basis for evaluating various impacts caused by training activities. In addition, the law requires that "...consideration of environmental factors must be integrated into existing Army procedures..."[1] This report is one of several which document research conducted at various Army installations to establish cause and effect relationships between Army activities and their impacts on ecosystems.[2] Studies are being conducted which document the effect of tracked vehicle activity for the lands and biota of installations representing four types of ecoregions: arid, semi-arid, temperate, and humid. The information obtained from this study at Fort Carson, CO, will help land-use planners make informed decisions regarding land rehabilitation, maintenance, and long-term management of lands used for training.

Objective

The objective of this report is to quantify the effects of Army training activities on the physical and biological properties of lands at Fort Carson.

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[1] R. K. Jain, L. V. Urban, and G. S. Stacey, Handbook for Environmental Impact Analysis, Technical Report E-59/ADA006241 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1974), p 13.

[2] W. D. Severinghaus, R. E. Riggins, and W. D. Goran, Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY, Special Report N-77/ADA073782 (USA-CERL, 1979), pp 1-64; W. D. Severinghaus and W. D. Goran, Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Hood, TX, Technical Report N-113/ADA109646 (USA-CERL, 1981), pp 1-22; W. D. Severinghaus and W. D. Goran, Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Lewis, Washington, Technical Report N-116/ADA111201 (USA-CERL, 1981), pp 1-45; V. E. Diersing and W. D. Severinghaus, Ecological Baseline--Piñon Canyon Maneuver Site, Colorado, Technical Report N-85/02 (USA-CERL, 1984).

Approach

Extensive field surveys were conducted on Fort Carson and the data analyzed to determine the effects of tracked vehicle training on mammals, birds, vegetation, and soils.

Mode of Technology Transfer

It is recommended that the information obtained in this study be used to develop predictive algorithms and an information base and then be incorporated into a computerized system for planning and maintenance of Army lands. Information on using this system will eventually be transmitted to the field by a Technical Manual.

2 GENERAL SITE DESCRIPTION

Fort Carson is located along the interface of the Great Plains and Rocky Mountains in central Colorado. The installation is largely limited to El Paso County with its southern and southwestern limits extending slightly into Pueblo and Fremont Counties, respectively. Fort Carson encompasses about 55,785 ha; its north-south length is nearly 39 km, and its greatest width is about 24 km. The eas rn side of the installation is characterized by gently to moderately sloping grasslands with relatively low relief. The western portion of the installation has wooded foothills, steep and rocky slopes, and higher elevations. The highest elevation on the post is 2121 m (6960 ft) on a ridge near State Highway 115; its lowest elevation is 1560 m (5120 ft) in the Beaver Creek Valley in the post's southeastern corner.

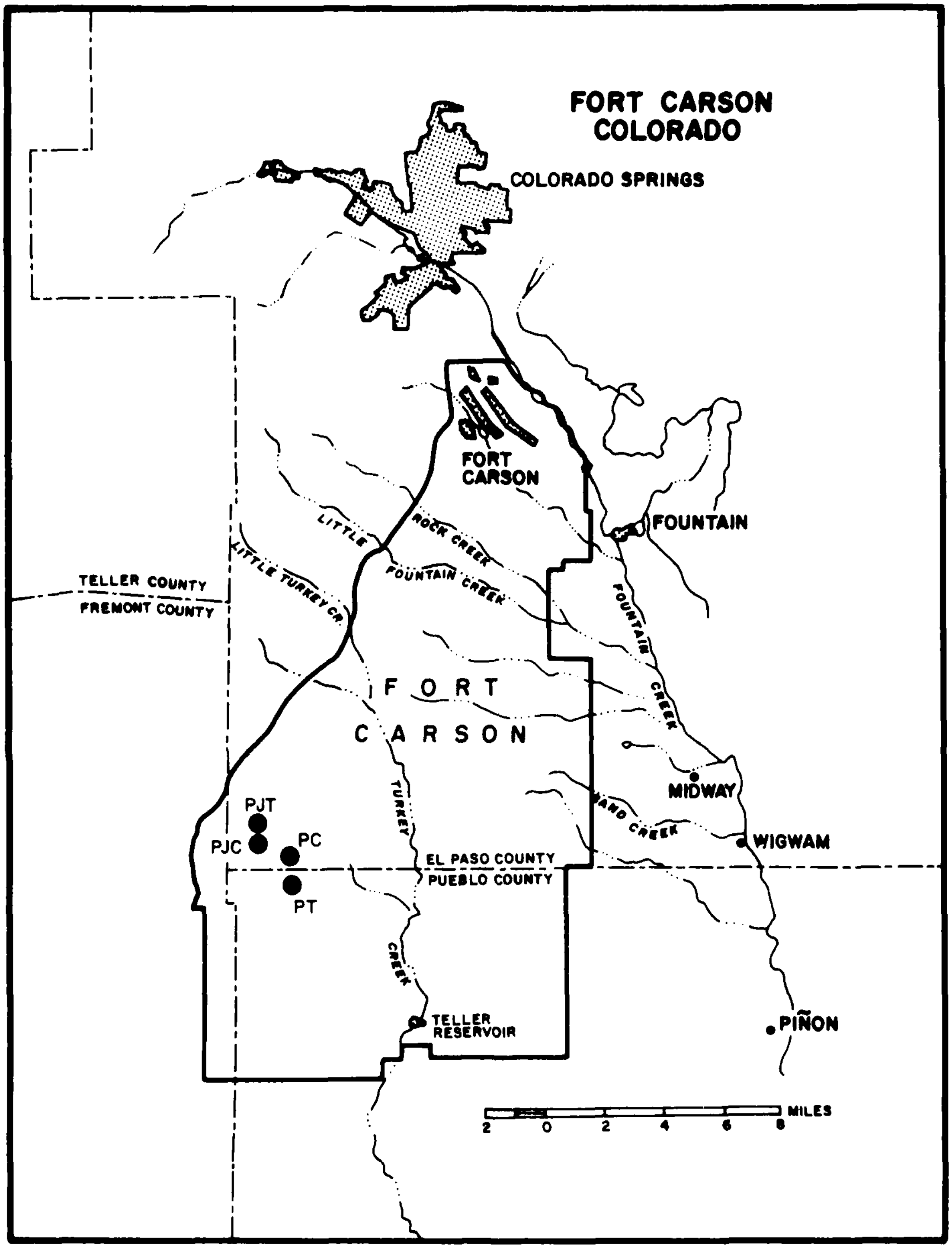
Intermittent streams on Fort Carson generally flow from northwest to southeast. Turkey Creek flows through the center of the installation and enters the Arkansas River south of the post. Rock Creek and Little Fountain Creek flow through the northern part of Fort Carson and enter the south-flowing Fountain Creek just east of the installation.

Fort Carson has cool summers and cold winters. The average annual temperature is about 73°F with an average annual humidity of 54 percent. Prevailing winds are from the north. Mean annual precipitation is about 380 mm, with slightly higher averages to the west and north and slightly lower averages to the south and east. Slightly more than 80 percent of the total annual precipitation is received from April through September.

Four sites were chosen for quantitative sampling: two within the shortgrass prairie and two within the pinyon-juniper woodland. These sites were picked based on the following criteria: (1) the two sites within each habitat type were to be similar in soils, topography, and plant species composition; (2) one of the sites was to be heavily used for tracked vehicle training; and (3) the other site was to be relatively undisturbed. These sites represent the major habitats where training was conducted.

Within the pinyon-juniper woodland habitat, the relatively undisturbed site, referred to as the pinyon-juniper control site or PJC (Figure 1), was located immediately west of Road 11 and about 4 km north of Camp Red Devil. One hundred and ninety (19 percent) of one thousand 1-m steps (based on 10- to 100-m randomly placed transects) intercepted tracked vehicle tracks. The pinyon-juniper test site (PJT) was located about 1 km north of the PJC site immediately west of Road 11. Three hundred and fifty-two (35 percent) of one thousand 1-m steps intercepted tracked vehicle tracks.

In the shortgrass prairie habitat, the relatively undisturbed site (the prairie control or PC site) was located 1 km east of Camp Red Devil in Sullivan Park about 600 m east of the landing strip. One hundred and fifty-two (8 percent) of two thousand 1-m steps intercepted tracked vehicle tracks. The prairie test (PT) site was located along each side of Road 8. Six hundred and forty-eight (32 percent) of two thousand 1-m steps intercepted tracked vehicle tracks.



PJC = pinyon-juniper control site
PJT = pinyon-juniper test site
PC = shortgrass prairie control site
PT = shortgrass prairie test site

Figure 1. Fort Carson, CO, and surrounding area.

3 METHODS FOR OBTAINING DATA

Soils

The baseline characterization of two soil parameters (bulk density and particle size distribution) involved the use of two different field methods: (1) bulk density sampling and (2) sampling of surface horizons for particle size distribution (texture) analysis. All sampling was done on May 21 and 22, 1983.

Particle Size Investigations

Sampling investigations were done to provide data for comparing particle size distributions within and between prairie and pinyon-juniper areas, and to characterize the baseline conditions. Samples were collected from the surface horizon, labeled, and placed in plastic bags. The hydrometer method was used to determine the percent by weight of sand, silt, and clay.[3] Nine samples were collected from each pinyon-juniper site, and eight samples were collected from the prairie sites.

Bulk Density Investigations

Bulk density samples were obtained from 16 soil pits in the PT and PJC sites. At each site, eight soil profiles, consisting of three horizons each, were sampled for bulk density analyses. Four of the profiles were taken in tracked areas and four in untracked areas. The soil profiles were examined to 1000 mm by hand augering. Generic soil horizons greater than 101.6 mm thick were sampled to depths of 600 mm, using a ring sampler and the core method.[4] Samples were labeled and stored in airtight plastic containers. Laboratory personnel determined the wet weight and the oven-dry weight for each sample. From these data, the bulk density and percent moisture for each sample were calculated using the following formulas:

$$\text{Bulk Density} = \frac{\text{Oven-Dry Weight (g)}}{\text{Volume (cm}^3\text{)}}$$

where the volume of the ring sampler equals 288.98 cm^3.

$$\text{Soil Moisture (\%)} = \frac{\text{Wet Weight - Oven-Dry Weight}}{\text{Dry Weight}} \times 100$$

The mean and the standard deviation of the bulk densities in the prairie and pinyon-juniper areas were calculated for comparison.

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[3] E. J. Felt, "Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling," Methods of Soil Analysis, Monograph 9 (American Society of Agronomy, 1965), pp 400-412.
[4] E. J. Felt, pp 400-412.

Vegetation

Vegetation transects originated from the bird survey transects (see p 13). Two parallel bird transects were established at each site; the prairie sites were separated by 250 m, and the pinyon-juniper sites were separated by 150 m. The two bird transects on each pinyon-juniper site were 400 m long and those on each prairie site were 1000 m long. Each vegetation study transect was 50 m long and originated from a designated point along the bird transects. On each prairie site, the vegetation transects originated at the points delineating 0, 200, 400, 600, 800 (or 1000) m on one bird transect, and from the odd-numbered points on the other bird transect (100, 300, 500, 700, and 900 m). Thus, 10 vegetation transects were established at each site. In the pinyon-juniper study sites, transects were staggered similarly, but were spaced closer together. On all four sites, each vegetation transect was measured from the bird transects along randomly generated compass bearings.

In each of the four study areas, intercepts of woody vegetation greater than 2 cm in diameter or 1 m in height were tallied by species, along ten 2- x 50-m transects.[5] Species importance and tree and shrub density and frequency were then determined from this information. Herbaceous vegetation and all plants less than 1 m in height were studied for plant cover in 1-m^2 quadrats placed systematically along the 50-m study transects at 5-m intervals. Ten quadrats were studied along each 50-m transect, and 100 quadrats were sampled in each study site. Random number generation was used to determine which of the ten quadrats in each transect would be evaluated for biomass. One quadrat was clipped to ground level. In the pinyon-juniper study sites, live and dead biomass were separated; in the prairie study sites, only graminoid and non-graminoid plants were separated from the sample quadrat. All biomass was clipped to a height of 2 m above the quadrats in order to estimate browse availability. Some nonbrowse plants (e.g., *Pinus edulis*) also occurred in the study quadrats and were clipped for a more complete estimate of the above-ground biomass. Biomass samples were air-dried for 1 week and weighed to the nearest gram on a spring scale.

Plant identifications follow Harrington.[6] Plant species lists were prepared for the early summer study period, and thus include spring plants and perennial species that might bloom later in the year, especially woody perennials that bloom in fall. Voucher specimens were collected and maintained in the USA-CERL Biological Inventory Collection.

The percent cover of study quadrats by bare ground, woody litter, and rock was measured to facilitate remote sensing programs for monitoring vegetation cover dynamics and the types and success of revegetation and reclamation.

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[5] D. Mueller-Dombois, *Aims and Methods of Vegetation Ecology* (John Wiley and Sons, 1974), pp 1-547.

[6] H. D. Harrington, *Manual of the Plants of Colorado* (The Swallow Press, 1964), pp 1-666.

Birds

Birds were surveyed using the combined transect methods of Emlen, Severinghaus, and Balph, Stoddart, and Balph.[7] Two parallel transects were established at each study site. On the prairie sites, these transects were each 1000 m long and separated from each other by 250 m. On the pinyon-juniper sites, the transects were each 400 m long and separated by 150 m. Transects were established by compass bearing and identified by placing .9-m-high flags at 50-m intervals on the prairie sites or 10-m intervals on the pinyon-juniper woodlands sites. Transects were walked slowly, starting at sunrise, for 10 days. As each transect was walked, the location of each bird detected along each side of the transect was recorded. The absolute density (birds per unit area) of each species was estimated by calculating the distance from the transect to the area where the detection of a species declines significantly. On each prairie site, the observable distance along each side of a transect was 50 m. This is a daily observable area of 2000 m by 100 m, or 20 ha. On each pinyon-juniper site, the observable distance along each side of a transect was 25 m. Therefore, 800 m by 50 m, or 4 ha of observable area was used.

The bird fauna occupying the four study sites were compared, using measures of species diversity, density, biomass, and guild structure. Significant differences were identified by using Student's t-test of the means. The weights of both birds and mammals were calculated using information given by Amadon, Armstrong, Baldwin and Kendeigh, Behle, Esten, Graber and Graber, Norris and Johnson, and Poole.[8]

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[7] J. T. Emlen, "Population Densities of Birds Derived from Transect Counts," Auk, Vol 88 (1971), pp 323-342; J. T. Emlen, "Estimating Breeding Bird Densities from Transect Counts," Auk, Vol 94 (1977), pp 455-468; W. D. Severinghaus, Guidelines for Terrestrial Ecosystem Survey, Technical Report N-89/ADA086526 (USA-CERL, 1980); M. H. Balph, L. C. Stoddart, and D. F. Balph, "A Simple Technique for Analyzing Bird Transect Counts," Auk, Vol 94 (1977), pp 606-607.

[8] D. Amadon, "Bird Weights and Egg Weights," Auk, Vol 60 (1943), pp 221-234; D. M. Armstrong, Distribution of Mammals in Colorado, Monograph No. 3 (Museum of Natural History, University of Kansas, 1972), pp 1-415; S. R. Baldwin and S. C. Kendeigh, "Variation in the Weight of Birds," Auk, Vol 55 (1938), pp 416-467; W. N. Behle, "Weights of Some Western Species of Horned Larks," Auk, Vol 60 (1943), pp 216-221; S. R. Esten, "Bird Weights of 52 Species of Birds (Taken from Notes of William Van Goider)," Auk, Vol 48 (1931), pp 572-574; R. R. Graber and J. W. Graber, "Weight Characteristics of Birds Killed in Nocturnal Migration," Wilson Bulletin, Vol 74, No. 1 (1962), pp 74-88; R. A. Norris and D. W. Johnson, "Weights and Weight Variations in Summer Birds from Georgia and South Carolina," Wilson Bulletin, Vol 70, No. 2 (1958), pp 114-129; E. L. Poole, "Weights and Wing Areas in North American Birds," Auk, Vol 55 (1938), pp 513-518.

Mammals

Small mammals were surveyed using 100 snap traps per night (92 Museum Specials and eight rat traps) at each site over a 10-day period (1000 trap-nights per site). These surveys were conducted during the same 10-day period as the bird surveys. At each site, the 100 traps were set parallel or along the full length of the bird transects. On the prairie sites, the traps were placed at 10-pace (≈ 10-m) intervals and on the pinyon-juniper sites, they were placed at four-pace (≈ 4-m) intervals. Each trap line was moved every 2 days in the following sequence: days 1 and 2, about 50 m outside one of the bird transects; days 3 and 4, about 50 m outside the other bird transect; days 5 and 6, midway between the two bird transects; days 7 and 8, along one bird transect; and days 9 and 10, along the other transect.

Traps were set and baited with a mixture of rolled oats and peanut butter each evening, and captures were removed each morning immediately after the morning bird counts. All mammals collected were placed in a plastic bag labeled with the date and place collected, frozen, prepared as scientific study specimens, and identified according to species.

Data collected included species diversity, total number collected per site, and actual capture numbers for each species by site. Chi-square tests were used to identify significant differences in the number of individuals of each species collected among the sites. The total biomass (in grams) of each guild was also compared among sites.

4 RESULTS

Soils

Particle Size Distribution

In the pinyon-juniper study sites, the A horizon was sampled in 18 different locations: nine times in the PJC site and nine times in the PJT site. Generally, the textures were silty loam in both sites, except in several areas where they were silty clay loam or loam. On the average, the PJC site contained more sand (66 percent versus 59 percent), less silt (20 percent versus 25 percent), and less clay (14 percent versus 16 percent) than the PJT site. However, all differences were not significant. Table 1 and Figure 2 present the particle size distribution data of all pinyon-juniper sampling locations.

On the prairie study sites, the A horizon was sampled in eight places on each site. The average texture on the PC site was silty loam to loam, and on the PT site, the average texture was silty loam. On the average, the prairie test site contained much more sand (72 percent versus 53 percent), much less silt (17 percent versus 32 percent), and less clay (11 percent versus 15 percent) than the PC site. Table 2 and Figure 3 show the particle size distribution data of all sampling locations.

Bulk Density

Bulk density analyses were conducted only at the PJC site. Of all eight soil profiles examined (each usually consisting of three horizons), four were from tracked areas and four were from untracked areas. In the tracked areas, 11 samples were collected; the mean bulk density was 1.46 g/cm^3, with a standard deviation of 0.17. In untracked areas, where 12 samples were collected, the mean density was 1.30 g/cm^3, with a standard deviation of 0.26.

The mean bulk density of the A horizon in tracked and untracked areas was 1.58 g/cm^3 and 1.21 g/cm^3, respectively; of the B horizon, 1.39 g/cm^3 and 1.29 g/cm^3, respectively; and of the C horizon, 1.44 g/cm^3 and 1.38 g/cm^3, respectively. Table 3 and Figure 4 show the bulk density data and soil horizons observed in these eight profiles.

In the prairie test site, eight soil profiles consisting of three horizons each were sampled to 600 mm for bulk density analyses. Four samples were taken in tracked areas and four in untracked areas. In the tracked areas, 12 samples were collected; the mean density of the samples was 1.52 g/cm^3, with a standard deviation of 0.11. In the untracked areas, 12 samples were collected; the mean density was 1.46 g/cm^3, with a standard deviation of 0.15. The mean bulk density of the A horizon in the tracked and untracked areas was 1.59 g/cm^3 and 1.50 g/cm^3, respectively; of the B horizon, 1.47 g/cm^3 and 1.51 g/cm^3, respectively; and of the C horizon, 1.50 g/cm^3 and 1.38 g/cm^3, respectively. Table 4 and Figure 5 present bulk density data and soil horizons observed in these eight profiles.

Table 1

Particle Size Distribution in Surface Horizons
of Pinyon-Juniper Study Sites

	Sand	Silt	Clay	Texture*	Depth (cm)
			Pinyon-Juniper Control Site		
	75	17	8	SL	0-5
	55	26	19	SL	0-5
	51	32	17	L	0-5
	58	23	19	SL	0-5
	71	19	10	SL	0-5
	74	8	18	SL	0-5
	60	28	12	SL	0-10
	67	20	13	SL	0-10
	81	11	8	LS	0-10
Mean	65.8	20.4	13.8		
			Pinyon-Juniper Test Site		
	70	17	13	SL	0-5
	53	32	15	SL	0-5
	60	28	12	SL	0-5
	57	28	15	SL	0-5
	59	24	18	SL	0-5
	57	21	22	SCL	0-5
	62	24	14	SL	0-5
	63	20	17	SL	0-5
	54	32	14	SL	0-5
Mean	59.4	25.1	15.6		

*SL = silty loam, LS = loamy sand, SCL = silty clay loam, L = loam.

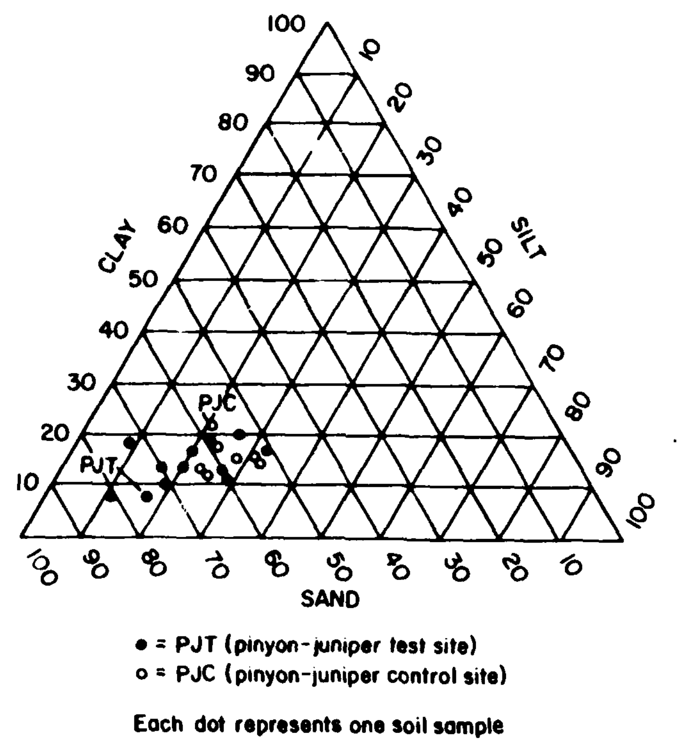

Figure 2. Soil particle size distribution of pinyon-juniper sites.

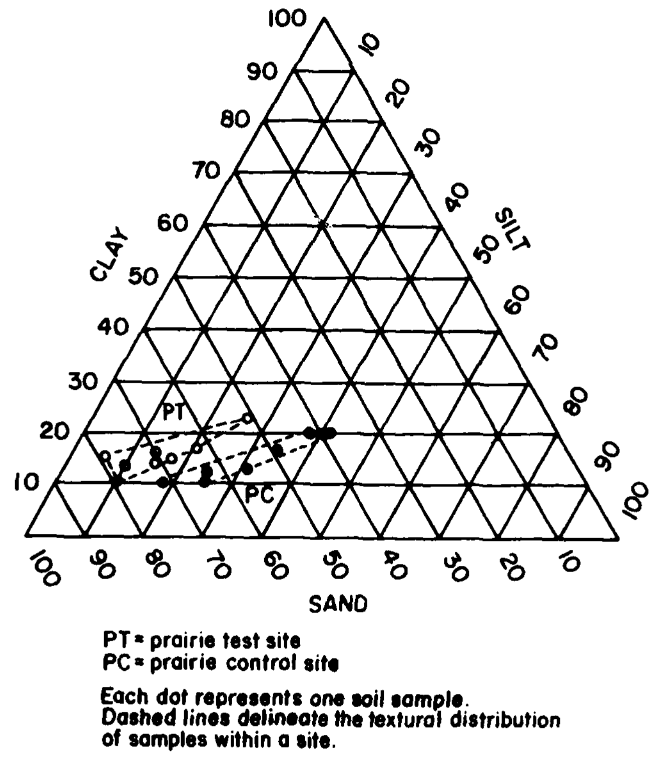

Figure 3. Soil particle size distribution of prairie sites.

Table 2

Particle Size Distribution in Surface Horizons
of Prairie Study Sites

	Sand	Silt	Clay	Texture*	Depth (cm)
			Prairie Control Site		
	72	18	10	SL	0-10
	65	25	10	SL	0-10
	56	31	13	SL	0-10
	65	25	10	SL	0-13
	40	40	20	L	0-10
	49	34	17	L	0-10
	41	39	20	L	0-13
	39	41	20	L	0-13
Mean	53.4	31.6	15.0		
			Prairie Test Site		
	79	11	10	SL	0-15
	75	14	11	SL	0-15
	74	20	6	SL	0-13
	76	18	6	SL	0-13
	62	23	15	SL	0-8
	60	25	15	SL	0-8
	74	13	13	SL	0-8
	73	14	13	SL	0-8
Mean	71.6	17.3	11.1		

*SL = silty loam, L = loam.

Table 3

Bulk Density and Soil Profiles of Pinyon-Juniper Control Study Site

Tracked Areas			Untracked Areas		
Hole No.	Soil Horizon	Bulk Density (g/cm^3)	Hole No.	Soil Horizon	Bulk Density (g/cm^3)
1	A	1.64	5	A	1.24
	Bt	1.41		Bt	1.45
	Bk	1.27		Bk	1.12
2	A*		6	A	1.36
	AC**	1.48		B	1.36
	C	1.32		C	1.19
3	A	1.43	7	A	0.77
	B	1.39		AC+	1.23
	C	1.17		C	1.17
4	A	1.66	8	A	1.49
	C	1.55		C	1.30
	C	1.72		C	1.86
Number of Samples		11			12
Mean		1.46			1.30

Tracked Areas	Untracked Areas
A horizon mean 1.58	A horizon mean 1.21
B horizon mean 1.39	B horizon mean 1.29
C horizon mean 1.44	C horizon mean 1.38

*This horizon is only 2.5 cm thick, so it was therefore not possible to sample.
**Is similar to this series, but moderately deep (51 to 102 cm to bedrock).
+Was considered a B horizon for purposes of averaging.

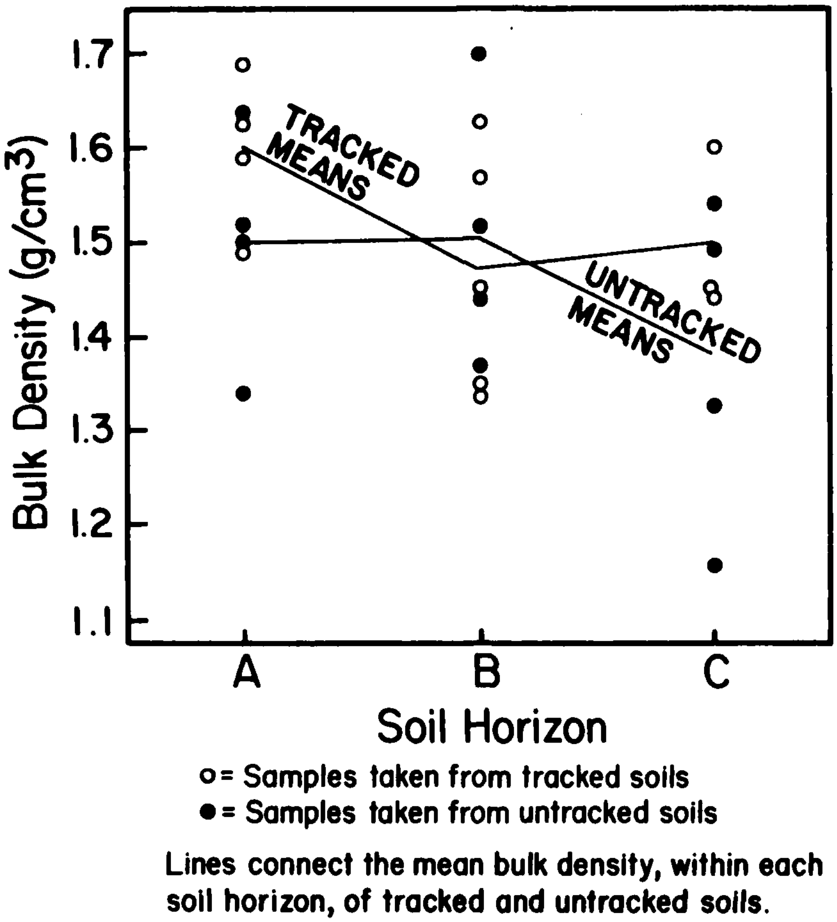

Figure 4. Bulk density of pinyon-juniper soils (control site only).

Vegetation

Woody Vegetation

The prairie control and test sites had no measurable woody vegetation. Based on density (Table 5), pinyon pine (Pinus edulis) dominated the pinyon-juniper control site with 670 per hectare. Mountain-mahogany (Cercocarpus montanus) was the second most abundant species, with an estimated 490/ha. Less abundant species were one-seed juniper (Juniperus monosperma) (280/ha), Rocky Mountain juniper (J. scopulorum) (30/ha), Gambel oak (Quercus gambelii) (40/ha), and skunk bush (Rhus trilobata) (10/ha). There were an estimated 1530 shrubs and trees/ha on the PJC site. In comparison, on the PJT site, Pinus edulis was dominant (310/ha), with Cercocarpus montanus and Juniperus monosperma both having 70/ha each. Less abundant species were Juniperus scopulorum (50/ha), Pinus ponderosa (10/ha), and Quercus gambelii (10/ha). There were an estimated 520 shrubs and trees/ha on the PJT site (Table 6).

Table 4

Bulk Density and Soil Profiles of Prairie Test Site

Tracked Areas			Untracked Areas		
Hole No.	Soil Horizon	Bulk Density (g/cm^3)	Hole No.	Soil Horizon	Bulk Density (g/cm^3)
9	A	1.63	13	A	1.52
	Bt	1.63		Bt	1.70
	Bk	1.45		Bk	1.44
10	A	1.48	14	A	1.50
	B	1.57		B	1.52
	Ck	1.44		Bk	1.37
11	A	1.58	15	A	1.33
	B	1.35		C	1.32
	Bk	1.33		C	1.16
12	A	1.68	16	A	1.63
	C	1.60		Ca	1.54
	C	1.45		C	1.49
Number of Samples		12			12
Mean		1.52			1.46

A horizon mean 1.59
B horizon mean 1.47
C horizon mean 1.50

A horizon mean 1.50
B horizon mean 1.51
C horizon mean 1.38

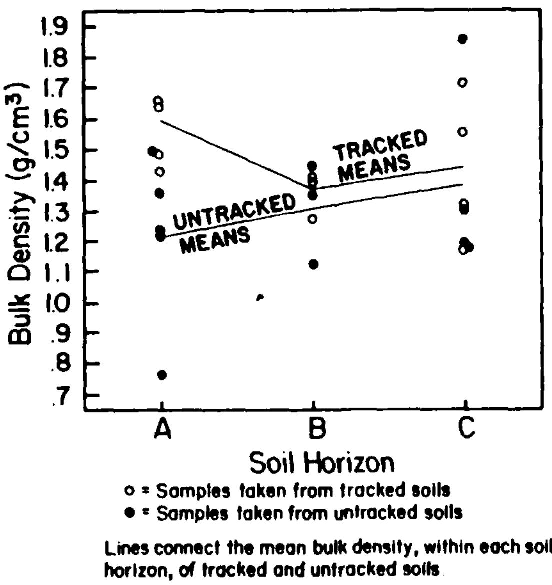

Figure 5. Bulk density of prairie soils (test site only).

Table 5

Density of Woody Species in Pinyon-Juniper Control Site
(Each column represents the number of each species intercepted along a 2- x 50-m random transect--total of 10 for the site.)

											Totals # /1000m²	Totals # /10,000m²
Cercocarpus montanus			3	8	10	4		11	5	8	49	490
Pinus edulis		11	10	6	13	8	7	7	1	4	67	670
Juniperus monosperma		4	1	5	4		3	2	8	1	28	280
Juniperus scopulorum	1					2					3	30
Quercus gambelii			1	1	1					1	4	40
Rhus trilolata									1		1	10
Totals											152	1520

Table 6

Density of Woody Species in Pinyon-Juniper Control Test Site
(Each column represents the number of each species intercepted along a 2- x 50-m random transect--total of nine for the site.)

										Totals # /1000m²	Totals # /10,000m²
Cercocarpus montanus		2	3	2						7	70
Pinus edulis	4	6	8	4	1	1	2	5		31	310
Pinus ponderosa					1					1	10
Juniperus monosperma	2	5								7	70
Juniperus scopulorum	1		2	1	1					5	50
Quercus gambelii			1							1	10
Totals										52	520

Tree and shrub species composition was very similar on the two pinyon-juniper sites. Both stands were dominated by the trees Pinus edulis and Juniperus monosperma and the shrub Cercocarpus montanus. The only significant difference between the tree and shrub vegetation on the two study areas was in the density of each species. The PJC area had 2.16 times as many Pinus, 2.58 times as many Juniperus, 4.0 times as many Quercus, and 7.0 times as many Cercocarpus. Apparently, there has been a greater reduction in the number of shrubs relative to the number of tree losses.

Plant Production

Plant production studies (Table 7) show an estimated average standing biomass of 126 g/m^2 on the PC site. Of this total, 23 g are forbs and 103 g are grasses. Total production for individual quadrats ranged from 75 g/m^2 to 195 g/m^2. On the PT site, there was an average total production of 77 g/m^2, significantly less ($p < .001$)* than on the PC site. Of this total, 31 g were forbs and 87 g were grasses. Tracked vehicle training reduces the percent cover of perennial grasses and increases the percent cover of "weedy" annuals.

Total plant production on the PJC site (Table 8) was an average 21 g/m^2, with 8 g/m^2 of this total representing forbs and 14 g/m^2 representing grasses. On the PJT site, total herbaceous production was 32 g/m^2. Of this total, 14 g/m^2 were forbs and 18 g/m^2 were grasses. Thus, total herbaceous production was higher on the PJT site than on the PJC site. Apparently, tracked vehicle training opens the canopy (reduces the number of trees and shrubs) and allows more forbs, and possibly grasses, to become established in the open areas.

In comparing the PC and PJC sites, total herbaceous production is much higher on the shortgrass prairie than on the PJC site (126 g/m^2 versus 21 g/m^2). This difference is due largely to increased grass production on the PC site (103 g/m^2 versus 14 g/m^2). Total forbs are very similar, with slightly higher production on the PC site (33 g/m^2 versus 8 g/m^2).

Quadrat Sampling

The quadrat sampling determined the cover (Table 9) and frequency (Table 10) of the various plants on the sites. On the PC site, the most common plant was blue grama grass, Bouteloua gracilis (76 percent of total vegetative ground cover). The next most common species (again based on cover) were: (1) a forb, Iva sp., which contributed 7.2 percent of total cover; (2) a grass (sand dropseed), Sporobolus cryptandrus, 4.2 percent cover; and (3) a grass (ring muhly), Muhlenbergia torreyi, 3.5 percent cover. In comparison, on the PT site, blue grama grass, the most common species, made up 47.8 percent of total ground cover, as compared to 76 percent on the PT site. The disturbance-related forb (Iva sp.) made up 24.8 percent of total cover, as compared to 7.2 percent on the PC site. Red three-awn (Aristida longiseta) was the third most common species, representing 6.2 percent of the cover. On the prairie control site, this species comprised 2.9 percent of the cover. The

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*p = probability.

Table 7

Plant Production (g/m^2) From Prairie Study Sites

Prairie Control Site			Prairie Test Site		
Herb	Grass	Total	Herb	Grass	Total
0.	185.0	185.0	45.0	85.0	130.0
0.	90.0	90.0	0.	70.0	70.0
55.0	130.0	185.0	100.0	0.	100.0
0.	90.0	90.0	80.0	65.0	145.0
100.0	95.0	195.0	0.	45.0	45.0
0.	75.0	75.0	0.	110.0	110.0
18.0	120.0	138.0	0.	60.0	60.0
0.	100.0	100.0	0.	20.0	20.0
55.0	50.0	105.0	80.0	10.0	90.0
0.	95.0	95.0	0.	0.	0.
22.8 ± 35.2	103.0 ± 36.2	125.8 ± 46.1	30.5 ± 4.5	86.5 ± 37.9	77.0 ± 46.9

Table 8

Plant Production (g/m^2) From Pinyon-Juniper Study Sites

Pinyon-Juniper Control Site			Pinyon-Juniper Test Site		
Herb	Grass	Total	Herb	Grass	Total
45.0	25.0	70.0	0.	85.0	85.0
(40.0)*	10.0	10.0	20.0	40.0	60.0
0.	5.0	5.0	45.0	20.0	65.0
10.0	25.0	35.0	75.0	30.0	105.0
(10.0)**	30.0	30.0	0.	0	0
20.0	40.0	60.0	0.	0	0
0.	0.	0.	0.	0	0
10.7	19.3	30.0	20.0	25.0	45.0

*Weight of *Cercocarpus montanus* (not included in analyses).
**Weight of *Pinus edulis* (not included in analyses).

Table 9

Summary of Ground Cover and Substrate Cover Types on All Study Sites (Data presented [mean ± standard deviation] is based on 100 1-m^2 quadrat samples in each study site.)

Substrate Type	PJC	PJT	PC	PT
Organic litter (needles and grasses)	7.4 ± 9.4	17.8 ± 10.8	--	--
Wood litter	3.9 ± 4.4	4.6 ± 4.8	--	--
Bare soil	80.4 ± 16.9	56.3 ± 16.4	63.6 ± 8.0	56.2 ± 15.1
Rock	3.9 ± 4.6	10.1 ± 12.2	--	0.2 ± 0.5
Live vegetative ground cover	~4%	~11%	~36%	~44%

Table 10

Summary of All Plants Sampled Less Than 1 m Tall on All Study Sites (Relative [%] cover and frequency for all plants sampled in 100 1-m^2 circular quadrats [per site] are given.)

	Fort Carson							
	PJC		PJT		PC		PT	
Species	%C	%F	%C	%F	%C	%F	%C	%F
Abronia fragrans					.10	.50		
Agropyron sp.							.20	.50
Allium spp.							.10	.30
Andropogon scoparius	.64	1.15	3.77	3.01				
Aristida longiseta	2.20	3.39	2.89	5.28	1.35	2.40	6.15	6.10
Argemone hispida			.10	.30	.10	.40		
Artemisia frigida	.45	.49	.55	.71				
Artemisia tridentata					1.00	1.70	1.20	.40
Astragalus spp.					.15	.50	.40	1.50
Astragalus missouriensis	.10	.32	.10	.48				
Bouteloua curtipendula	.94	.88	5.40	4.96				
Bouteloua gracilis	15.50	12.02	22.06	16.40	76.00	32.50	47.80	17.90
Bromus tectorum	1.76	.33						

Table 10 (Cont'd)

	Fort Carson							
	PJC		PJT		PC		PT	
Species	%C	%F	%C	%F	%C	%F	%C	%F
Cadaria draba					.05	.20		
Carex spp.	.05	.16	.53	.87				
Cercocarpus montanus	8.70	2.87	7.31	1.91				
Chenopodium album	.08	.23					.05	.20
Cirsium undulatum							.10	.20
Convolvulus arvensis					.10	.70		
Cryrtantha jamasii	.04	.32	.28	1.45				
Cymopterus montanus	.34	.66	.61	1.21	.10	.70	.65	1.60
Descurianna pinnata							.10	.30
Echinocerus viridiflorus					.70	3.10	.05	.40
Erigeron canadensis	1.98	.75	.33	1.21	.30	.80	.20	.50
Eurotica lanata					.10	.50	.20	.20
Eriogonum spp.	3.99	3.57	.87	2.40			.20	.50
Festuca sp.	7.35	5.12	5.76	4.65				

Table 10 (Cont'd)

	Fort Carson							
	PJC		PJT		PC		PT	
Species	%C	%F	%C	%F	%C	%F	%C	%F
Gaura coccinea			.03	.14	.25	1.50	.25	.80
Gayophyton sp.	.02	.16	.16	.88	.05	.20	.10	.40
Gilia aggregata	.07	.33	1.71	2.96				
Gutierrezia sarothrae	1.84	2.34	6.82	4.85	.05	.20		
Happlopappus spinulosa	.42	.98	.07	.44	.10	.30	.60	3.20
Helianthus annuus	1.06	2.73	.44	1.55	.65	3.10	1.10	5.40
Helianthus occidentalis		P		P		P		P
Helitropium sp.		P		P		P		P
Hilaria jamesii		P		P		P		P
Hymenoxys acaulis		P						P
Ipomopsis aggregata		P		P		P		P
Impomopsis spicata		P		P				
Iva sp.	7.35	5.29	.12	.26	7.20	7.30	24.75	25.40
Juniperus monosperma		P		P				
Juniperus scopulorum	2.33	.32	6.39	.83				

Table 10 (Cont'd)

	Fort Carson							
	PJC		PJT		PC		PT	
Species	%C	%F	%C	%F	%C	%F	%C	%F
Kochia scoparia		P	6.80	3.45		P		P
Lappula redowskii	.23	.73	.80	2.71	.70	1.80	.90	3.20
Lathyrus sp.		P		P		P		P
Lepidium virginicum		P		P	.05	.30	.05	.20
Lesquerella fendleri	.02	.16	.68	1.86				
Lesquerella ovalifolia	.10	.50		P				
Linum lewisii	.45	1.30	.10	.48			.40	.60
Linum puberulum		P		P		P	.10	.60
Lithospermum incisum	.48	1.05	.55	1.57			.10	.20
Lupinus kingii					.40	1.40	.15	.60
Medicogo sativa	.17	.32						
Melampodium cinercum	.10	.16		P		P		P
Mentzelia spp.		P		P	.10	.20	.05	.20
Microsteris gracilis		P		P		P		P
Microsaris cuspidata		P		P		P		P

Table 10 (Cont'd)

	Fort Carson							
	PJC		PJT		PC		PT	
Species	%C	%F	%C	%F	%C	%F	%C	%F
Muhlenbergia torreyi		P	.32	.71	3.45	8.70	2.10	3.00
Oenothera albicaulis			.21	.81	1.20	3.10	.65	2.90
Opuntia arborescens						P		P
Opuntia polycantha	.05	.16	1.94	.44	.25	.50	.70	.70
Oryzopsis hymenoides		P		P		P	.10	.50
Oxytropis lambertii		P		P				
Penstemon angustifolius	.12	.32	.29	.79	.05	.20		
Physalis lobata	.61	1.19		P		P	.85	1.40
Pinus edulis	2.75	2.63	7.58	4.17				
Pinus ponderosa		P		P				
Plantago purshii		P	.39	1.66	.20	1.50	.55	3.70
Polygonum sp.						P	.40	.60
Pseudocymopterus sp.		P		P		P		P
Ratibida tagetes	15.34	11.56		P		P	.15	.72
Rhus trilobata	.02	.33		P				

Table 10 (Cont'd)

	Fort Carson							
	PJC		PJT		PC		PT	
Species	%C	%F	%C	%F	%C	%F	%C	%F
Ribes aureum				P				
Rumex hymenosepalus						P		P
Salsola kali	8.57	13.20	.46	1.75	.95	3.10	3.00	7.20
Senecio mutablis			.3	.14				
Sitanion hystrix	.31	.99	.24	.68	.85	4.60	.60	2.60
Solanum spp.		P		P		P		P
Sonchus sp.	.09	.32					.30	1.00
Sphaeraclea coccinea	1.28	2.48		P	1.90	4.10	2.80	3.50
Sporobolus cryptandrus	1.25	1.32	.24	.48	4.15	12.89	.65	1.60
Stipa viridula						P	.90	1.20
Taraxacum officinale						P		P
Tradescantia occidentalis							.05	.40
Tragopogon dubius	.10	.16	.08	.44				
Teucrinum laciniatum					.25	.60		P
Townsendia exscapa						4	.05	.10
Unknown basal rosette	.34	.40						

Table 10 (Cont'd)

	Fort Carson							
	PJC		PJT		PC		PT	
Species	%C	%F	%C	%F	%C	%F	%C	%F
<u>Unknown</u> <u>canascent</u> alt. lf. shrub			.12	.26				
<u>Unknown</u> <u>compositae</u>	.10	.16		P				
<u>Unknown</u> <u>grass</u>	.10	.16						
<u>Unknown</u> <u>lichens</u>		P	P		P	P		
<u>Unknown</u> <u>moss</u>	.46	.40	.12	.26	P	P		
<u>Unknown</u> <u>seedlings</u>	4.15	7.86	.33	.18				
<u>Unknown</u> <u>shrub</u>					.05	.20		
<u>Viola</u> <u>nuttallii</u>					.05	.20	.15	.60
<u>Yucca</u> spp.	P				.05	.20	.60	.30
<u>Quercus</u> <u>gambelii</u>		P	4.85	.55				

*P = Present, but in inconsequential numbers.

fourth most common species--another disturbance indicator--was Russian thistle (Salsola kali), which made up 3.0 percent of the cover.

On the PC site, three of the four most common species were perennial grasses, which together made up 83.7 percent of the total vegetative ground cover. The other species (Iva sp.) was a forb indicative of disturbance (7.2 percent). In comparison, on the PT site, only two of the four most common plants were grasses. They comprised 54.0 percent of the total cover. The other two species were invaders, or disturbance-related forbs, and made up 27.8 percent of the total cover.

On the pinyon-juniper control site, the most common herbaceous plant was blue grama grass (15.5 percent of total vegetative ground cover). The next most common species was a forb (Ratibda tagetes), which comprised 15.3 percent of the cover. Mountain-mahogany (Cercocarpus montanus), a shrub, was the next most common (8.7 percent), followed by the forb, Russian thistle (Salsola kali), at 8.6 percent). In comparison, on the PJT site, blue grama grass was the most common (22.0 percent)--slightly higher than on the PJC site). The next most common plant was mountain mahogany (7.3 percent)--slightly lower than on the PJC site, followed by snakeweed (Gutierrezia sarothrae--a half-shrub--(6.8 percent), and a forb, kochia (Kochia scoparia) (6.8 percent).

Birds

Prairie Sites

The two prairie sites had very similar bird fauna (Table 11). Four species (mourning dove, horned lark, western meadowlark, and lark sparrow) were common to both sites. The lark bunting was limited to the PT site, and an unidentified sparrow (not a lark sparrow) was limited to the PC site. There was no statistically significant difference in the number of each species between sites.

On each site, the horned lark was the most common species, and the meadowlark was the second most common species. Together these two represented 74 percent of the total individuals seen on the PT site and 89 percent noted on the PC site. The mourning dove, lark bunting, and lark sparrow made up the remainder of the bird fauna on the two sites. Several other species of birds were seen near, but not on, one or both of the study sites. These included a burrowing owl near the PT site, scaled quail near the PC site, black-billed magpie flying adjacent to the PC site, rock wren and Say's phoebe along the banks of a deep wash near the PT site, cliff swallow flying over the PC site, and several ravens and/or crows over each site.

The total biomass of birds on each site was much the same, with 3529 g on the PT site and 3816 g on the PC site. Horned larks and meadowlarks together comprised 81 percent of the total biomass on the PT site and 92 percent on the PC site (Table 12). The biomass of the other species was closely comparable.

Guild theory was also applied to the Fort Carson bird data. This theory assumes that species belonging to the same guild use similar resources in much the same ways.[9] Table 12 lists the four guilds found on each site. Guild 28,

Table 11

Avian Species--Densities and Biomass on Prairie Sites

Species List	Test No./100 ha	Test g/100 ha	Control No./100 ha	Control g/100 ha	Guild
Mourning dove	2	264	1	132	8
Horned lark	25	675	33	891	1a
Western meadowlark	20	2200	24	2640	28
Lark bunting	1	26	0	0	1b
Lark sparrow	13	364	5	140	1b
Sparrow (unknown kind)	0	0	1	13	1b
		3529 g		3816 g	

Table 12

Bird Guilds of Prairie Sites

Guild	Primary Guild Characteristics	Biomass Test	Biomass Control	Frequency (%)* Test	Frequency (%)* Control	Frequency** Difference
1a	Seedeating, bare ground	675	891	19	23	4
1b	Seedeating, open field	390	153	11	4	7+
8	Mast/grain, small, brush/field	264	132	7	3	4
28	Omnivorous, open field	2200	2640	62	69	7*

*Frequency: The biomass of each guild expressed as a percent of the total biomass for each site.
**Frequency difference: Within a guild, the difference in frequency between sites.
+Major differences within a guild between sites.

dominant guild on both sites. Guild 1a, containing the seed-eating, bare-ground-loving horned lark, was the second most dominant guild. The two remaining guilds, 16 and 8, made up most of the species present, but only 18 percent of the total biomass at the PT site and 7 percent at the PC site.

Pinyon-Juniper Sites

Seventeen species were found on both sites combined (Table 13). Of these, eight were common to both sites, three were limited to the PJT site, and six were limited to the PJC site. Several species were found near, but not on, the study sites: a great blue heron that flew over the PJT site; several meadowlarks observed within 200 m of both sites (pinyon-juniper woodland/shortgrass prairie ecotone area); several ravens and/or crows seen over each site; a common night-hawk observed flying over the PJT site; and several mourning doves heard singing near both sites. The numbers of the eight species common to both sites were about the same between the two sites. The most common species on both sites were the chipping sparrow, rufous-sided towhee, plain titmouse, and black-headed grosbeak. Together, these four species made up 79 percent of the total number of individuals seen on the PJT site and 60 percent on the PJC site. Uncommon species common to both sites were the ash-throated flycatcher, gray flycatcher, solitary vireo, and lark sparrow.

Table 13

Avian Species--Densities and Biomass on Pinyon-Juniper Sites

Species	Test		Control		
List	No./100 ha	g/100 ha	No./100 ha	g/100 ha	Guild
Test and Control					
Ash-throated flycatcher	3	87	8	232	13
Gray flycatcher	3	42	8	112	13
Plain titmouse	15	315	10	210	5
Solitary vireo	3	45	5	75	14
Black-headed grosbeak	5	240	15	720	2
Rufous-sided towhee	30	1170	13	507	3
Lark sparrow	8	224	5	140	1b
Chipping sparrow	53	689	30	390	1b
Test Only					
Broad-tailed hummingbird	3	15			6
Western wood-pewee	5	60			13
Pinyon jay	3	255			30
Control Only					
Scrub jay			5	425	30
Red-breasted nuthatch			3	54	15
Mountain bluebird			5	180	12
Warbling vireo			3	39	14
Brown-headed cowbird			3	132	30
Western tanager			1	33	2
		3142 g		3249 g	

The total biomass of birds on each site was almost the same, with 3249 g/100 ha on the PJC site and 3142 g/100 ha on the PJT site. The four most common species on each site (chipping sparrow, rufous-sided towhee, plain titmouse, and black-headed grosbeak) together accounted for 1477 g on the PJC site and 2414 g on the PJT site.

Guild theory was also applied to the Fort Carson bird data. Figure 6 illustrates, in a bivariate analysis, that the open-field/edge guilds 1b and 3, containing the rufous-sided towhee, lark sparrow, and chipping sparrow, increase with the opening of the pinyon-juniper woodland due to training; it also shows that the woodland guilds 2 and 13, containing the ash-throated flycatcher, gray flycatcher, black-headed grosbeak, western wood-pewee, and western tanager, decrease with the opening of the woodlands. These four guilds show the greatest change (Table 14) between the PJC and PJT sites and can be referred to as the impact or indicator guilds to habitat change. These four guilds made up 80 percent of the total biomass on the PJT site and 66 percent on the PJC site. The other guilds (5, 6, 12, 14, 15, and 30) showed little change between the two sites and/or were relatively unaffected by training-induced impact (opening of the woodlands.)

Mammals

Prairie Sites

Nine species of small mammals were recorded on the shortgrass prairie sites (Table 15). Of these, all were common to both sites but one--the plains harvest mouse (Reithrodontomys montanus)--which was limited to the PC site and was represented by only one individual. There are three major differences between the mammal fauna on the two prairie sites: (1) mammals are much more abundant on the PT site (178 individuals versus 102, $p < .005$); (2) there is an inverse relationship between the numbers of kangaroo rats (Dipodomys ordii) and pocket mice (Perognathus flavus) on the two sites; and (3) there are many more white-footed mice (Peromyscus leucopus, $p < .005$) on the PT site. The first two differences can be readily explained on the basis of soil texture and competitive interactions between kangaroo rats and pocket mice.

It is well known that rodents burrow in soils for shelter; therefore, the sandier the soil, and thus the easier to dig, the greater the number of individuals present if all else is equal. The average sand component was 72 percent on the PT site (178 individuals collected) and 53 percent on the PC site (102 individuals collected). Also, kangaroo rats are competitors of pocket mice.[10] Since kangaroo rats are large-bodied, it is hard for them to burrow in "tight" soils. In their absence, the smaller pocket mouse becomes relatively abundant, such as on the PC site (27 kangaroo rats and 10 pocket mice collected). On sandy soils, such as the PT site, the kangaroo rat excludes many pocket mice (49 kangaroo rats and three pocket mice collected).

[10] C. Lemen and P. W. Freeman, "Quantification of Competition Among Coexisting Heteromyids in the Southwest," The Southwestern Naturalist, Vol 28 (1983), pp 41-46.

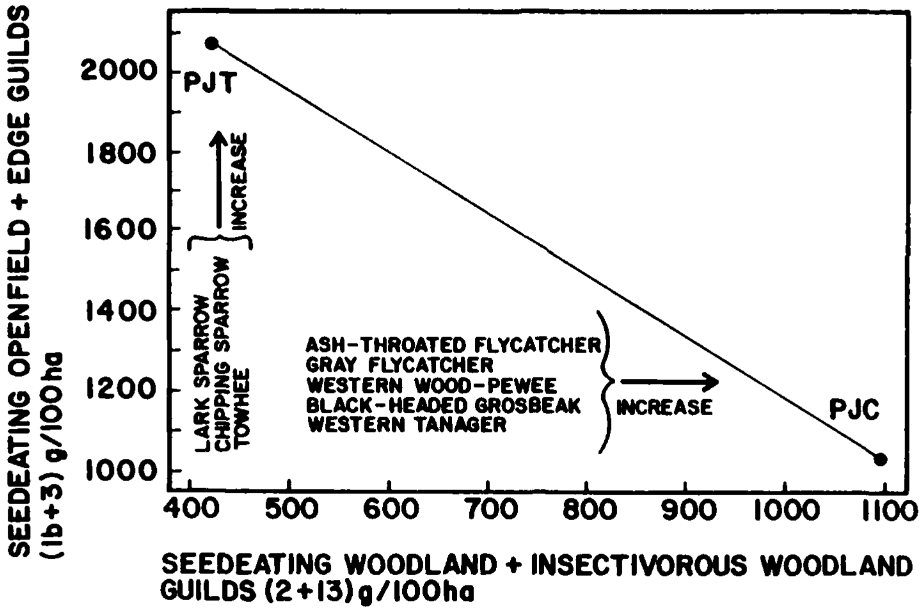

Figure 6. Bivariate analysis contrasting the proportion (in biomass) of woodland guilds and open-field/edge guilds on PJC and PJT sites.

Table 14

Bird Guilds of Pinyon-Juniper Sites

Guild	Primary Guild Characteristics	Biomass Test	Biomass Control	Frequency (%)* Test	Frequency (%)* Control	Frequency** Difference
1b	Seedeating, open field	913	530	29	16	13+
2	Seedeating, woodland	240	753	8	23	15+
3	Seedeating, edge	1170	507	37	16	21+
5	Fruit/seed, woods edge	315	210	10	6	4
6	Nectar	16	-	-	-	0
12	Insectivorous, sallying, open	-	180	6	6	0
13	Insectivorous, sallying, woodland	189	344	1	11	10+
14	Insectivorous, gleaner, large	45	114	1	4	3
15	Insectivorous, gleaner, small	-	54	-	2	2
30	Omnivorous, mixed, non-ground	255	557	8	17	9+

*Frequency: The biomass of each guild expressed as a percent of the total biomass for each site.
**Frequency difference: Within a guild, the difference in frequency between sites.
+Major differences within a guild between sites.

The third significant faunal difference between the two sites (significant increase of white-footed mice on the PT site) reflects soil/vegetation disturbance created by tracked vehicle training. The white-footed mouse is an inhabitant of "...brushy and weedy parts of grasslands."[11] The increased number of disturbance forbs (weeds) on the PT site, such as Russian thistle (Salsola kali), sunflower (Helianthus annuus), and Iva sp., is favored habitat for the white-footed mouse. This disturbance, which obliterates grass and establishes annual weeds, is entirely correlated with increased tracked vehicle use (8 percent on the PC site and 32 percent on the PT site).

Three pinyon mice (Peromyscus truei) were collected on the PT site, and one was taken on the PC site. This species is typically a resident of pinyon-juniper woodland; the four individuals collected in the open prairie were apparently dispersals (young adults) from nearby stands of pinyon-juniper.

Four guilds of mammals were present on the prairie site (Table 16). These guilds were no. 2 (carnivorous grasshopper mouse guild), no. 9 (diurnal ground squirrel guild), no. 11 (nocturnal, seed-eating, nonnest-building pocket mice, and kangaroo rat guild), and no. 12 (nocturnal, seed- and foliage-eating, nest-building, white-footed mouse, and harvest mouse guild). On the PT site, guild 11 made up 43 percent (3206 g) of the total biomass, and on the PC site, it made up 54 percent (1825 g) of the total. Guilds 2 and 12 were also very similar on the two sites. Guild 2 accounted for 9 percent of the total biomass on each site, while guild 12 accounted for 28 percent of the total on the PT site and 29 percent on the PC site. Guild 9, which contains the spotted ground squirrel (Spermophilus spilsoma), was much more common on the PT site (20 percent of total biomass) than on the PC site (7 percent of the total). This difference does not reflect training-induced impacts, but instead is evidence of this species' requirement to live in sandy soil (53 percent sand on the PC site and 72 percent sand on the PT site). Armstrong notes that this species "...inhabits areas of sandy soil on the Great Plains in eastern Colorado..."[12]

Pinyon-Juniper Sites

Twelve species of small mammals were recorded on the pinyon-juniper sites (Table 15). Of these, seven were common to both sites, two were limited to the PJT site (the brush mouse--Peromyscus boylii, and the long-tailed vole--Microtus longicaudus), and three were limited to the PJC site (the grasshopper mouse--Onychomys leucogaster, the white-throated woodrat--Neotoma albigula, and the Mexican woodrat--Neotoma mexicana). The 11 individuals making up these latter five species were incidental to the collection efforts; their presence or absence on a site does not represent a response to tracked-vehicle training in the pinyon-juniper woodlands. On the PJT site, the two long-tailed voles were collected along the grassy bank of a small spring and the one brush mouse was collected in a rocky outcrop. On the PJC site, the four woodrats, representing two species, were taken under several rocky overhangs, and the four grasshopper mice were taken in a small, natural, grassy clearing.

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[11] D. J. Schmidly, The Mammals of Trans-Pecos Texas (Texas A&M University Press, College Station, 1977), pp 1-225.

[12] D. M. Armstrong, Distribution of Mammals in Colorado, Monograh No. 3 (Museum of Natural History, University of Kansas, 1972), pp 1-415.

Table 15

Mammal Capture Data

Species (scientific name)	Pinyon-Juniper Captures Test		Pinyon-Juniper Captures Control		Prairie Captures Test		Prairie Captures Control
Eutamias quadrivittatus (59)*	18	<.005**	4	<.005**	-		-
Spermophilus spilosoma (113)	-		-	<.005**	13	<.005**	2
Dipodomys ordii (65)*	6		3	<.005**	49	<.025**	27
Perognathus flavus (7)	7		2		3		10
Reithrodontomys megalotis (12)	21		19		20		18
Reithrodontomys montanus (11)	-		-		-		1
Onychomys leucogaster (35)	-		4	<.005**	18		9
Peromyscus leucopus (29)	23	<.005**	7		38	<.005**	9
Peromyscus maniculatus (19)	20		30	<.001**	34		25
Peromyscus boylii (24)	1		-		-		-
Peromyscus truei (26)	12		14	<.005**	3		1
Neotoma albigula (219)	-		3		-		-
Neotoma mexicana (242)	-		1		-		-
Microtus longicaudus (34)	2		-		-		-
Total individuals/site	110		87		178	<.005**	102

*Average weight in grams of each species.
**Statistically significant differences (0.05 level and above).

Table 16

Mammal Guilds on All Four Sites

Guild Number	Species or Group	PJT	PJC	PT	PC
2	*Onychomys leucogaster* (grasshopper mouse)	30g(0)*	140 g(5)	630 g(9)	315 g(9)
7	*Microtus* (voles)	68(2)	0(0)	0(0)	0(0)
9	*Eutamias-Spermophilus* (chipmunks and ground squirrels)	1062(33)	236(8)	1469(20)	226(7)
10	*Neotoma albigula* (woodrat)	0(0)	899(32)	0(0)	0(0)
11	*Perognathus-Dipodomys* (pocket mouse-kangaroo rat)	439(14)	209(7)	3206(43)	1825(54)
12	*Peromyscus-Reithrodontomys* (white-footed mice and harvest mice)	1635(51)	1365(48)	2066(28)	989(29)
	Total biomass/site	3204 g	2849 g	7371 g	3355 g

*Frequency: The biomass of each guild expressed as a percent of the total for each site.

The numbers of the seven remaining species common to both sites were about the same between the two sites except the white-footed mouse (*Peromyscus leucopus*), which was most common on the PJT site ($p < .005$), and the Colorado chipmunk (*Eutamias quadrivittatus*) also most common on the PJT site ($p < .005$). The white-footed mouse occupies disturbed habitats where "weedy" forb species occur. This is the case on the PJT site where weedy species increased because tracked vehicle training increased. Also, the Colorado chipmunk was significantly more common on the PJT site. This species not only requires coniferous woodlands to live in, but prefers "...open coniferous woodlands."[13] Apparently, this species' increase on the PJT site is due to its preference for a more open woodland (opened by a loss of trees to training) or perhaps the increased availability of debris (broken tree limbs and tree trunks) for shelter.

Six guilds of mammals were present on the pinyon-juniper sites. Of these, guilds 2 and 10 (the carnivorous grasshopper mouse guild and the den-dwelling woodrat guild) were limited to the PJC site, and guild 7 (the grass-eating vole guild) was limited to the PJT site. The presence or absence of each of these three guilds was due to unique microhabitats within each site and did not result from training impacts. The remaining three guilds (9, 11, and 12), all common to both sites, comprised most of the total biomass. Guild 12 (white-footed mice and harvest mice) made up 51 percent of the total biomass on the PJT site and 48 percent on the PJC site, and are therefore of similar proportions. Guild 11, a seed-eating guild (pocket mice and kangaroo rats), had more than twice the biomass on the PJT site (14 percent of total) than on the PJC site (7 percent of total). With the reduction of the canopy cover on the PJT site, more herbaceous, seed-producing plants were able to become established, thereby supporting a larger population of open-area, seed-eating small mammals (guild 11). Guild 9 was also more abundant on the PJT site (33 percent of total biomass compared to 8 percent on the PJC) because of the increase in debris (broken limbs and split and fallen tree trunks) available as shelter to chipmunks.

[13] D. M. Armstrong, *Distribution of Mammals in Colorado*.

5 DATA ANALYSIS

Table 17 provides a general account of the major floral and faunal differences distinguishing the pinyon-juniper woodland and shortgrass prairie habitats.

Soils

Aside from a loss of vegetation cover, physical changes to the soils are readily apparent in tracked versus untracked areas. There is little doubt that the pass of a tracked vehicle partially destroys the soil structure (aggregation), which greatly increases the A horizon's susceptibility to erosion. An increase in bulk density also compounds the erosion problem. In the pinyon-juniper control and prairie test sites, bulk density increased in the A horizon of the tracked and untracked areas by about 31 percent and 6 percent, respectively. In the B horizon, bulk density of tracked areas in the PJC site increased by 8 percent but decreased by 3 percent on the PT site. This latter figure is apparently biased by one variant reading (1.70 versus three other readings of 1.44, 1.52, and 1.37). In the C horizon, bulk density increased by 4 percent in the PJC site and by 9 percent in the PT site. Combining all three horizons into a common sample, bulk density increased by 14 percent in the tracked areas over the untracked areas on the PJC site, and increased by 4 percent in the tracked areas on the PT site.

Field tests made by Turnbull and Foster[14] show that the density of the compacted soil will vary with water content, nature of the soil material, and the compactive force. The compactive force is influenced specifically by the number of passes, the total weight of the compactive equipment, and the pressure per unit area. Air-dried soil does not compact readily, nor does it compact to a high density. As the water content increases, it compacts more readily and to a greater density. Generally, the water content for maximum compaction increases as soil texture becomes finer. At the water content of maximum compaction, water films around soil particles are thick enough to lubricate the particles and yet thin enough not to occupy space other soil particles could occupy. Plowing of compacted layers has been shown to increase the saturated hydraulic conductivity and porosity of soils.[15] It has been shown[16] that plowing is more effective than chiseling or discing in ameliorating compacted soil layers beneath the plowed surface horizons.

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[14] W. J. Turnbull and C. R. Foster, "Proof Rolling of Subgrades. In: Soil Compaction and Proof Rolling of Subgrades," Natural Resource Council, High-Way Research Bulletin, Vol 254 (1960), pp 12-21.

[15] D. K. Cassel, "Spatial and Temporal Variability of Soil Physical Properties Following Tillage of Norfolk Loamy Sand," Soil Sci. Society of America, Vol 47 (1983), pp 196-201.

[16] W. B. Voorhees, C. G. Senst, and W. W. Nelson, "Compaction and Soil Structure Modification by Wheel Traffic in the Northern Corn Belt," Soil Sci. Soc. Am., Vol 42 (1978), pp 344-349.

Table 17

Characteristic Features of Biota of Pinyon-Juniper Woodland and Shortgrass Prairie (Control Sites Only)

	Pinyon-Juniper Woodland		Shortgrass Prairie
Mammals			
Most abundant species	*Peromyscus maniculatus* *Reithrodontomys megalotis* *Peromyscus truei* (together 71% of all individuals collected)	somewhat (similar)	*Dipodomys ordii* *Peromyscus maniculatus* *Reithrodontomys megalotis* (together 70% of all individuals collected)
Diversity	10	(similar)	9
Captive index (captures/1000 trapnights)	87	(similar)	102
Biomass index (based on capture/1000 trapnights)	2849 g	(similar)	3355 g
Faunal similarity		50% (different)	
Birds			
Most abundant species	chipping sparrow rufous-sided towhee plain titmouse black-headed grosbeak (together 60% of all individuals seen)	(different)	horned lark meadowlark (together 89% of all individuals seen)
Diversity	14	(different)	5
Density	114/100 ha	(different)	64/100 ha
Biomass	3249 g/100 ha	(similar)	3816 g/100 ha
Faunal similarity		0% (different)	
Vegetation			
Most abundant species (based on ground and canopy cover)	*Pinus edulis* *Juniperus monosperma* *Bouteloua curtipendula* *Bouteloua gracilis* *Ratibida tagetes*	(different)	*Bouteloua gracilis* *Muhlenbergia torreyi*
Diversity	70	(similar)	57
Plant production	30 g/m^2	(different)	126 g/m^2
Percent ground cover (vegetation)	11%	(different)	36%
Floral similarity		38% (moderately different)	

Tracked vehicle traffic at Fort Carson has compacted the soils. These compacted areas apparently persist with lower porosity[17] (lower aeration and lower infiltration rates),[18] increased bulk density (hindering of root penetration and plant growth),[19] and changes in soil structure (disaggregation); this increases runoff and creates gullied, bare strips of land.

Vegetation

Shortgrass Prairie

On the prairie at Fort Carson, the principal effect of tracked vehicle training on vegetation has been to reduce perennial grass cover and increase "weedy" forbs. During the spring, many areas on the prairie on which tanks have turned sharply and obliterated the grass cover look pinkish-white from the flowers of evening primrose (Oenothera albicaulis) that have invaded the tracked areas. Other disturbance-related forbs are the Iva sp. forb, Russian thistle (Salsola kali), and sunflower (Helianthus annuus). These disturbance-related species are most common on the PT site, where tracked vehicle impacts were 32 percent (based on foot transects) compared to only 8 percent on the PC site. Plant production on the prairie habitat is relatively high, so the effects of disturbance are of short duration.

Pinyon-Juniper Woodland

In the pinyon-juniper habitat on Fort Carson, the principal effect of tank travel on the vegetation has been to reduce canopy (tree) cover and shrub cover, and to slightly increase herbaceous vegetation. The PJT site, where tracked vehicle training was the most intense, contained about 45 percent as many pinyon and juniper trees as the PJC site (980 versus 440). Tracked vehicle training on the shrub layer was even more apparent; the PJT site contained only 15 percent as many shrubs as the PJC site (540 versus 80). The training effects on the woody vegetation included shearing of limbs, root exposure, and fragmentation of fallen trees. The net effect of this reduction in canopy cover by tracked vehicle training is an apparent increase in the herbaceous cover. Much of this is due to the invasion of weedy species, such as the half-shrub snakeweed (Gutierrezia sarothrae) and the disturbance-related forb, kochia (Kochia scoparia). Total plant productivity in the pinyon-juniper habitat is relatively low, so disturbances have a long-lasting impact. Since training activities on the PJT site began after 1965, and the condition of the site was assessed in 1983, it is certain that the current level of use cannot continue indefinitely without damaging the vegetation to the extent that the site will be of poor quality for training.

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[17] A. K. Sharda, "Influence of Soil Bulk Density on Horizontal Water Infiltration," Austr. J. Soil Res., Vol 15 (1977), pp 83-86.

[18] N. C. Brady, The Nature and Property of Soils (MacMillan Publishing Co., 1974), pp 1-60.

[19] G. R. Blake, W. W. Nelson, and R. R. Allmaras, "Persistence of Subsoil Compaction in a Mollisol," Soil Sci. Soc. Am., Vol 40 (1976), pp 943-948.

Birds

Tracked vehicle training on the Fort Carson pinyon-juniper woodlands has not changed bird diversity. There has also not been any change in total bird biomass between the PJC and PJT sites. However, there has been a marked increase in the number and biomass of open-field and edge-seeking species and a definite decrease in the number and biomass of the woodland species. If Fort Carson accelerates its use of these lands, there will be a continued replacement of woodland individuals with edge and open-field species. Analyses in a similar habitat (cedar-oak woodland) at Fort Hood demonstrated similar results. At Fort Hood, there was a 63 percent impact (based on foot transects) on the test site, compared to 35 percent on the Fort Carson test site; at Fort Carson, this resulted in a shift in the relative number of open-field/edge individuals to woodland individuals, as well as the complete replacement of some woodland species by open-field/edge species.

Tracked vehicle training on the Fort Carson shortgrass prairie has not resulted in any apparent significant change in the bird fauna. However, there were indications that the number of meadowlarks decreased, which can be interpreted as a decrease in total grass cover. Similar studies in prairie habitat at Fort Lewis demonstrated that some prairie species were eliminated; this occurred in areas where there was a 62 percent impact, as compared to a 32 percent impact at the Fort Carson PT site. If training is increased on the Fort Carson prairies, there may be significant changes in the bird fauna; however, the current level of training has had little effect on them.

Mammals

Comparison of the control and test sites showed that some small mammals of the pinyon-juniper woodlands demonstrated a moderate response to tactical vehicle activity. The white-footed mouse and the Colorado chipmunk increased on the PJT site apparently due to an increase in "weedy" forbs (a result of reduction in canopy cover) and an increase in woody debris (tree stumps, downed logs, and large broken limbs). On the other hand, these impacts did not signficantly decrease the number of other small mammals.

In the shortgrass prairie, there was a similar change in the small mammal fauna with increased impact. With the loss of some of the grass cover and the establishment of "weedy" forbs, the white-footed mouse, which prefers "weedy" habitats, increased significantly on the PT site.

6 CONCLUSIONS

This report has described the effects of Army training activities on the physical and biological properties of lands at Fort Carson. The following effects were observed on the pinyon-juniper woodland:

1. Soils: Disaggregation and increased bulk density (average of 14 percent increase through the A, B, C horizons combined), with a resultant decrease in water infiltration and increase in soil erosion.

2. Vegetation: 55 percent reduction in tree canopy cover, 85 percent reduction in shrub cover, and an increase in herbaceous cover with overall low productivity (slow repair) on the site.

3. Birds: A 101 percent increase in biomass of the open-field and edge guilds and a 61 percent reduction in the biomass of the woodland guilds.

4. Mammals: An increase in species favoring more "weedy" and open habitats.

The following effects were noted on the shortgrass prairie:

1. Soil: Disaggregation and increased bulk density (average of 4 percent increase through the A, B, C horizons combined), with a resultant decrease in water infiltration and increase in soil erosion.

2. Vegetation: A reduction of perennial grass cover, with a corresponding increase in "weedy" forbs, with overall high productivity (fast repair) on the site.

3. Birds: A 17 percent decrease in the grassy open-field guild (meadowlark).

4. Mammals: An increase in species favoring a "weedy" habitat.

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Arsenals
Pine Bluff 71611

Rocky Mountain 80022

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Electronic Proving Ground 85613
ATTN: STEEP-LS-S

Jefferson Proving Ground 47250
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Yuma Proving Ground 85364
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Indiana 47111
ATTN: SARIO-EN
Iowa 52638
ATTN: SARIO-EN
Kansas City 67357
ATTN: SARKA-FE

Army Ammunition Plants
Lake City 64056
ATTN: SARLC-O-F
Lone Star 75501
ATTN: SARLS-EN
Longhorn 75670
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Louisiana 71102
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Institute for Water Resources 22060
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Arlington, VA 22202

Office of Mgmt Svc, MS 110-FAA [illegible]

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